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(54) **POLYAMIDE-46 MULTIFILAMENT AND SEWING THREAD FOR AIRBAG**

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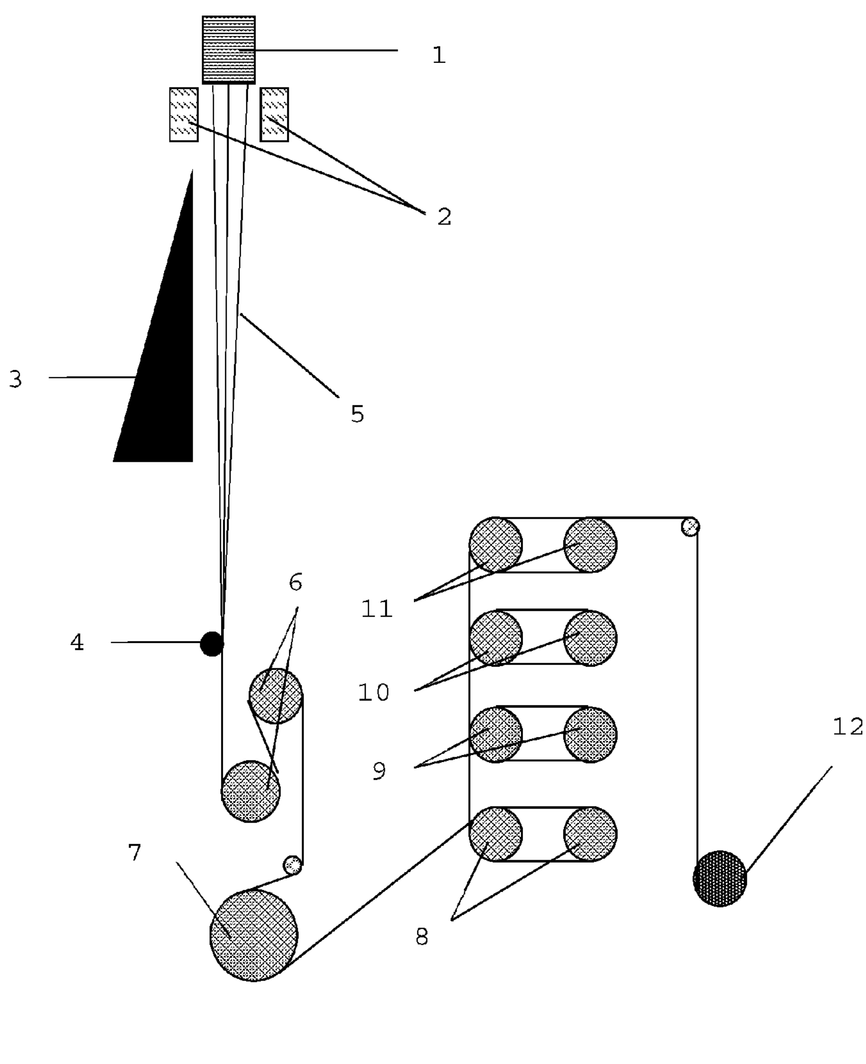
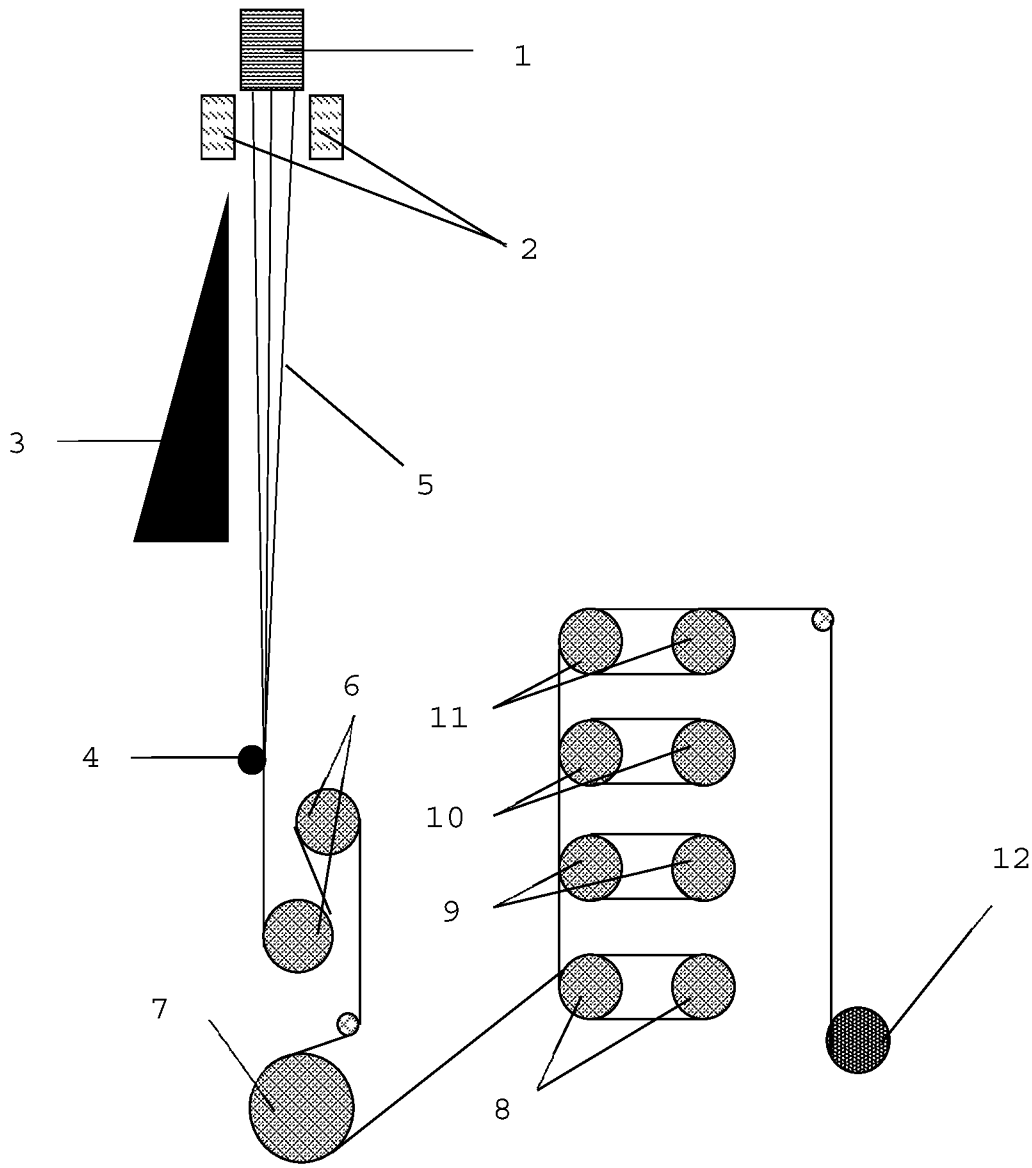
(57) **ABSTRACT**

A purpose of the present invention is to provide a polyamide-46 multifilament that has high strength, high-temperature dimensional stability, and excellent stretchability, which have not been attained with any conventional technique, and that is hence suitable for use as a sewing thread for airbags having mechanical properties which can inhibit the sewed portions from suffering an air leakage of a high-temperature high-power gas. The polyamide-46 multifilament has the following physical properties (1) to (3). (1) A strength of 6.0-9.0 cN/dtex and an elongation of 15-30%. (2) A degree of elongation E10 (100° C.), as measured after stretching 10 times in a 100° C. environment, of less than 1.0%. (3) A difference between the elongation under a load of 2.0 cN/dtex at ordinary temperature and the elongation under a load of 2.0 cN/dtex in a 100° C. environment of less than 0.5%.

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POLYAMIDE-46 MULTIFILAMENT AND SEWING THREAD FOR AIRBAG

TECHNICAL FIELD

[0001] The present invention relates to a polyamide-46 multifilament and a sewing thread for airbag.

BACKGROUND ART

[0002] Multifilaments of polyamide 6 (also referred to as "polycaprolactam") and polyamide 66 (also referred to as "polyhexamethylene adipamide") have higher strength and elongation and superior fluff quality as compared with general-purpose multifilaments of polyester, polypropylene, or the like, and are therefore used in a wide variety of applications such as airbags, tire cords, sewing threads, transmission belts, ropes, and fishing nets.

[0003] Among the above-described applications, polyamide 66 has been used for many years in the field of sewing threads from the viewpoint of high mechanical properties and heat resistance thereof.

[0004] In contrast to polyamide 66, polyamide 46 has a higher melting point and higher heat resistance, and therefore is excellent in dimensional stability in high temperature, and therefore is a material particularly suitable for a sewing thread for airbags, and a technique for improving strength by improving spinning and drawing conditions is disclosed (Patent Document 1).

[0005] In addition, a technique for improving dimensional stability in high temperature (Patent Documents 2 and 3) has also been disclosed, and an invention for further improving the characteristics of polyamide 46 has been reported so far.

[0006] However, almost no technique for improving the stretchability of a polyamide-46 multifilament has been disclosed, and no technique for achieving both thermal dimensional stability and stretchability has been disclosed so far.

[0007] As a method for imparting stretchability to a general-purpose polyamide multifilament, for example, a method is disclosed in which a polyamide multifilament of a partially drawing yarn is used as a sheath yarn, and is subjected to a taslan process with the polyamide multifilament of a core yarn (Patent Document 4). However, such a conventional stretchability developing technique is an original yarn design that impairs strength, and is difficult to apply to industrial applications requiring high strength.

[0008] Conventional techniques do not provide a polyamide-46 multifilament suitable for sewing threads for airbag with all of high strength, high thermal dimensional stability, and excellent stretchability.

[0009] Then, in view of the development trend of airbags, weight reduction and compactness are required as a recent trend of airbags, and with the compactness of inflators, generated gas tends to have higher temperature and higher output.

[0010] However, the increase in temperature of the gas causes an increase in thermal damage to the airbag base fabric, and also causes a loss in mechanical properties of the sewing thread, particularly tends to stretch under a high-temperature atmosphere, and thus increases gas leakage due to an opening of the sewing portion.

[0011] In addition, the increase in gas output tends to increase the pressure due to the gas at the time of deploying the airbag, leading to an increase in gas leakage from the base fabric of the airbag, particularly from the sewing portion, causing such a problem that the performance as the airbag cannot be satisfied.

[0012] In order to solve this problem, various kinds of sewing thread for airbags have been proposed (Patent Documents 5 and 6). In Patent Document 5, a sewing thread for airbags containing 50% or more of a fiber material having a melting point of 300° C. or more is examined, and an extremely high retention ratio of heat resistance is clearly shown. On the other hand, the high-temperature dimensional stability is not specified, and the stretchability of the sewing thread is not studied.

[0013] Patent Document 6 shows that setting the elongation for the sewing thread and the elongation for the base fabric within specific ranges improves the followability of the sewing thread to the inflatable base fabric when the airbag is deployed, and the air permeability of the sewing portion is suppressed, but the stretchability of the sewing thread is not considered. Furthermore, the high-temperature dimensional stability of the sewing thread when the airbag is deployed has not been studied.

PRIOR ART DOCUMENTS

Patent Documents

[0014] Patent Document 1: Japanese Patent Laid-open Publication No. 59-88910

[0015] Patent Document 2: Japanese Patent Laid-open Publication No. 59-76914

[0016] Patent Document 3: Japanese Patent Laid-open Publication No. 1-168914

[0017] Patent Document 4: Japanese Patent Laid-open Publication No. 2002-249943

[0018] Patent Document 5: Japanese Patent Laid-open Publication No. 6-235136

[0019] Patent Document 6: Japanese Patent Laid-open Publication No. 2012-188006

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0020] An object of the present invention is to provide a polyamide-46 multifilament having high strength, high-temperature dimensional stability, and excellent stretchability and suitable for the sewing thread for airbags having mechanical properties capable of suppressing air leakage from an airbag sewing portion due to a high-temperature and high-output gas as described above.

Solutions to the Problems

[0021] The present invention has been intensively studied to solve the above problems, and mainly has the following configurations.

[0022] (1) A polyamide-46 multifilament having the following physical properties.

[0023] When a degree of elongation after 10 times of stretching at a strength of 6.0-9.0 cN/dtex, an elongation of 15-30%, and an environment at 100° C. is set to E10 (100° C.), E10 (100° C.)<1.0%, and when an elongation at a load of 2.0 cN/dtex and ordinary temperature is M (R.T.), and the elongation at a load of 2.0 cN/dtex and an environment at 100° C. is set to M (100° C.), M (100° C.)−M (R.T.)<0.5%.

[0024] (2) The polyamide-46 multifilament according to (1), having the following physical properties.

[0025] When the degree of elongation after 10 times of stretching at ordinary temperature is set to E10 (R.T.), and the degree of elongation after 10 times of stretching at ordinary temperature after heat treatment at 120° C. for 24 hours is set to E10' (R.T.), E10' (R.T.)−E10 (R.T.)≤0%. When the elongation at a load of 2.0 cN/dtex and ordinary temperature is set to M (R.T.), and the elongation at a load of 2.0 cN/dtex and ordinary temperature after heat treatment at 120° C. for 24 hours is set to M' (R. T.), M' (R.T.)−M (R.T.)≤0%.

[0026] (3) The polyamide-46 multifilament according to the above (1) or (2), having a total fineness of 300-2300 dtex and a single filament fineness of 2-20 dtex.

[0027] (4) The polyamide-46 multifilament according to any one of (1) to (3), wherein sulfuric acid relative viscosity nr is $3.0<\eta r<4.5$.

[0028] (5) A sewing thread for airbags, including the polyamide-46 multifilament according to any one of the above (1) to (4) .

Effects of the Invention

[0029] Using the polyamide-46 multifilament of the present invention for sewing an airbag can suppress air leakage from an airbag sewing portion due to a high temperature and a high output gas during deployment of the airbag.

BRIEF DESCRIPTION OF THE DRAWING

[0030] FIG. **1** is a schematic view of one embodiment of a step of producing the polyamide-46 multifilament (melting step is omitted).

EMBODIMENTS OF THE INVENTION

[0031] Hereinafter, the polyamide-46 multifilament of the present invention will be described.

[0032] In order to achieve the above object, the polyamide-46 multifilament of the present invention is made of a polyamide resin. The polyamide resin is a polyamide resin containing polyamide 46 as a main component. The polyamide 46 having a high melting point contained as a main component can provide a multifilament having high heat resistance.

[0033] It is preferable to use a polyamide resin the 98% by mass or more of which among the total mass of the polyamide resin excluding additives described later is made of polyamide 46, and it is more preferable that the polyamide resin includes only polyamide 46.

[0034] The polyamide resin may be a copolymerized polyamide obtained by copolymerizing polyamide 46 with another polyamide, and polyamide 6, polyamide 66, polyamide 610, or polyamide 612 may be used as another polyamide to be copolymerized. The polyamide resin may be a mixture of polyamide 46 and another polyamide.

[0035] The sulfuric acid relative viscosity of the polyamide resin is preferably 3.3-5.0, more preferably 3.5-4.5. The polyamide resin having a sulfuric acid relative viscosity exceeding 5.0 contributes to deterioration of stringiness, and frequently induces yarn breakage and fluffing during drawing process. The polyamide resin having a sulfuric acid relative viscosity of less than 3.3 is difficult to provide the polyamide-46 multifilament having a predetermined sulfuric acid relative viscosity nr to be described later. The sulfuric acid relative viscosity refers to a value measured by a method described in the section of Examples described later.

[0036] The polyamide resin in the present invention may contain additives such as an end-capping agent including monocarboxylic acid, a matting agent including titanium oxide, a polymerization catalyst or heat stabilizer including a phosphorus compound, and an antioxidant or heat stabilizer including a copper compound and a halide of an alkali metal or an alkaline earth metal as components other than polyamide, as necessary.

[0037] The content ratio of the additive contained in the polyamide resin is preferably less than 5% by weight, and more preferably less than 3% by weight. If the content ratio of the additive is 5% by weight or more, the strength of the multifilament is reduced.

[0038] In addition, among the additives described above, particularly the heat stabilizer having a function of suppressing thermal degradation of the polymer is contained in an amount of preferably 250-7000 ppm, more preferably 500-5000 ppm. The heat stabilizer may be used singly or in combination of two or more. If the content of the heat stabilizer is less than 250 ppm, the suppression of thermal degradation of the polymer is limited, and the stretch characteristics and dimensional stability after aging at a high temperature tend to be slightly impaired. On the other hand, adding the heat stabilizer in an amount of more than 7000 ppm decreases the strength and elongation of the fiber.

[0039] The sulfuric acid relative viscosity nr of the polyamide-46 multifilament of the present invention is preferably $3.0<\eta r<4.5$, more preferably $3.3<\eta r<4.2$, and still more preferably $3.5<\eta r<4.0$. Setting the sulfuric acid relative viscosity nr within such a range can produce the polyamide-46 multifilament having sufficient crystal orientation with good yarn productivity.

[0040] The total fineness of the polyamide-46 multifilament of the present invention is preferably 300-2300 dtex, and more preferably 400-1700 dtex. Setting the total fineness to 300 dtex or more cab suppress the generation of fuzz during thermal drawing. Furthermore, the melting time of the polymer is not excessively prolonged, and thus thermal decomposition of the polymer can be suppressed. In addition, setting the total fineness to 2300 dtex or less can provide the polyamide-46 multifilament excellent in mechanical properties without impairing uniformity of cooling after melt-spinning.

[0041] The number of single fibers of the polyamide-46 multifilament of the present invention is preferably 30-350, more preferably 50-250. If the number of the single fiber is less than 30, the single filament fineness is increased, the cooling efficiency during melt spinning is lowered, and the flexibility of the multifilament is lost. In addition, if the number of the single fiber is more than 350, the single filament fineness becomes thin, and fuzz is easily generated.

[0042] In addition, the cross-sectional shape of the single fiber is not particularly limited. In addition to a round cross section, cross sections having various shapes such as a flat shape, a polygonal shape, different shapes including a Y shape and an X shape, and a hollow shape can be adopted. Fibers having a plurality of cross-sectional shapes may be mixed.

[0043] The strength of the polyamide-46 multifilament of the present invention is 6.0-9.0 cN/dtex, more preferably 7.0-9.0 cN/dtex. It has been found that the strength range is an essential range for obtaining the polyamide-46 multifilament having stretchability due to the crystal orientation of polyamide 46, and is an essential characteristic for a polyamide multifilament for a sewing thread for airbags. If the strength is less than 6.0 cN/dtex, not only the durability as a sewing thread for airbags is insufficient, but also the crystal orientation is lowered, thus failing to provide the polyamide-46 multifilament having stretchability. If the polyamide-46 multifilament having a strength of more than 9.0 cN/dtex is to be obtained, mechanical drawing at a high ratio is required, failing to provide a sufficient elongation as a sewing thread for airbags.

[0044] The elongation (breaking elongation) of the polyamide-46 multifilament of the present invention is 15-30%, and more preferably 18-28%. If the elongation is in such a range, a polyamide multifilament suitable for a sewing thread for airbags is obtained. Furthermore, it has been found that due to the amorphous orientation of polyamide 46, the range of the elongation amorphous is essential for obtaining the high-temperature dimensional stability. If the elongation is less than 15%, impact absorption due to expansion and contraction becomes insufficient when a load is applied to the airbag sewing portion, and durability as a sewing thread cannot be maintained. Furthermore, the orientation of the amorphous portion becomes excessively large, failing to provide the polyamide-46 multifilament having the high-temperature dimensional stability. If the polyamide-46 multifilament having an elongation of more than 30% is to be obtained, sufficient strength as a sewing thread for airbags fails to be obtained.

[0045] The polyamide-46 multifilament of the present invention has less than 1.0% of a degree of elongation after stretching 10 times under an environment at 100° C., E10 (100° C.), more preferably less than 0.8%. Within such a range, returning after expansion by the pressure at the time of deploying the airbag is good, the followability of the sewing thread to the inflatable base fabric is good, and the internal pressure retention performance is improved. If E10 (100° C.) is 1.0% or more, reduction of air leakage from the sewing portion is insufficient.

[0046] In the polyamide-46 multifilament of the present invention, the difference between the elongation under a load of 2.0 cN/dtex at ordinary temperature, M (R.T.), and the elongation under a load of 2.0 cN/dtex at 100° C., M (100° C.), (M (100° C.)−M (R.T.)) is less than 0.5%, more preferably less than 0.3%, and still more preferably less than 0.1%. Within such a range, the dimensional stability as the sewing thread is not impaired even under a high-temperature atmosphere at the time of deploying the airbag, so that the filling effect can be exhibited. If the numerical value (M (100° C.)−M (R.T.)) is 0.5% or more, it means that the sewing thread easily stretches due to heat reception in airbag deployment, which causes misalignment of the sewing portion and is insufficient for reducing air leakage.

[0047] In the polyamide-46 multifilament of the present invention, the difference between the degree of elongation after stretching 10 times at ordinary temperature, E10 (R.T.) and the degree of elongation after heat treatment at 120° C. for 24 hours when the fiber is subjected to 10 times of tensile tests at ordinary temperature, E10' (R.T.), (E10' (R.T.)−E10 (R.T.)) is preferably 0% or less. Within such a range, it is possible to suppress the stretch characteristic loss due to the aging in the sewing thread, the process of sewing, and the airbag storage environment.

[0048] In the polyamide-46 multifilament of the present invention, the difference (M' (R.T.)−M (R.T.)) between the elongation M (R.T.) under a load of 2.0 cN/dtex at ordinary temperature and the elongation M' (R.T.) under a load of 2.0 cN/dtex at ordinary temperature after heat treatment at 120° C. for 24 hours is preferably 0% or less. Within such a range, it is possible to suppress deterioration in dimensional stability due to the aging in the sewing thread, the process of sewing, and the airbag environment.

[0049] FIG. **1** schematically shows a machine for direct spinning and drawing preferably used in the present invention. Hereinafter, an embodiment of the method for producing a polyamide-46 multifilament of the present invention will be described with reference to FIG. **1** as an example.

[0050] The polyamide-46 multifilament of the present invention is preferably produced by melt spinning, and as described above, the sulfuric acid relative viscosity of the polyamide 46 chips used for melt spinning is preferably 3.3-5.0, more preferably 3.5-4.5. Within such a range, it is possible to stably obtain the polyamide-46 multifilament having a high strength in a state where stringiness is good.

[0051] The moisture content of the polyamide 46 chips is preferably 1300 ppm or less, more preferably 800 ppm or less. Adjusting the chip moisture content to such a value can maintain the sulfuric acid relative viscosity of the polyamide-46 multifilament of the present invention within the range, and thus can achieve the strength level of the original thread required for the sewing thread for airbags. If the chip moisture content exceeds 1300 ppm, hydrolysis is promoted during polymer melting, and high strength cannot be obtained due to insufficient crystal orientation. In addition, the stretchability of the polyamide-46 multifilament is lost, failing to achieve the E10 (100° C.) as defined in the present invention.

[0052] The polyamide 46 chips are melted, kneaded and spun by an extruder spinning machine, and the melting is preferably performed in a vacuum environment. Under a vacuum environment, the pressure at the chip supply port of the extruder is preferably less than 5 kPa, and more preferably less than 3 kPa (hereinafter, a pressure of less than 5 kPa is defined as under vacuum).

[0053] Unlike other aliphatic polyamides which are thickened at the time of melting to produce a high-molecular-weight product, the polyamide 46 has a property of decomposing at the time of melting to produce a low-molecular-weight product. The decomposition mechanism can be roughly classified into thermal decomposition, oxidative decomposition, and hydrolysis, and melting under vacuum eliminates oxygen in water and air, and limits the decomposition mechanism only to thermal decomposition, and thus can suppress decomposition of the polymer. Suppressing decomposition during melting can maintain the high molecular weight of the polymer constituting the multifilament, and thus can produce a highly crystal-oriented polyamide-46 multifilament. If the pressure is 5 kPa or more under vacuum, hydrolysis during melting fails to be suppressed, and high strength fails to be obtained due to insufficient crystal orientation. As a result, it is difficult for the polyamide-46 multifilament to achieve the stretchability E10 (100° C.) defined in the present invention.

[0054] The spinning temperature is set to 10-50° C. higher than the melting point of the polymer chip, and melt spinning is performed from a spinneret **1** having discharge holes of preferably 30-350, more preferably 50-250.

[0055] It is preferable that a range of 5-300 cm from immediately below the spinneret **1** is surrounded by a heating hood **2**, and the melt-spun yarn is passed through a high temperature atmosphere of −30−+30° C. relative to the chip melting point. The high-temperature atmosphere for passing is more preferably a melting point of −30−+15° C.

[0056] Slowly cooling the spun yarn through a high-temperature atmosphere surrounded by the heating hood **2** without immediately cooling the spun yarn allows the molecular orientation of the melt-spun polyamide-46 polymer to be relaxed and the molecular orientation uniformity among the single fibers to be enhanced, and thus can increase the strength of the polyamide-46 filament.

[0057] On the other hand, if cooling is performed immediately without passing through the high-temperature atmosphere, the orientation of the undrawn yarn is enhanced, and the variation in the orientation degree among the single fibers is increased. Such an undrawn yarn loses its drawability, and as a result, the highly crystal-oriented polyamide-46 multifilament of the present invention may not be obtained.

[0058] The undrawn yarn that has passed through the above step is cooled and solidified by blowing air at 10-80° C., preferably 10-50° C. by a cross flow cooling device **3**. A case where the cooling air temperature that is less than 10° C. is not preferable because a large cooling device is required in this case. If the cooling air exceeds 80° C., an air volume is required, and single fiber swaying increases, and thus collision or the like between the single fibers occurs, which causes deterioration of yarn productivity.

[0059] The undrawn yarn that has been cooled and solidified is preferably subjected to multi-stage drawing, particularly two-stage or three-stage drawing. Specifically exemplifying the case of three-stage drawing in FIG. **1**, first, an oil agent is applied to the cooled and solidified undrawn yarn by an oil supply device **4**, and the undrawn yarn is taken up by a take-up roller (1FR) **6**. The take-up roller is typically non-heated.

[0060] Thereafter, the yarn is wound in the order of a feeding roller (2FR) **7**, a first drawing rollers (1DR) **8**, a second drawing roller (2DR) **9**, a third drawing roller (3DR) **10**, and a relaxing roller (RR) **11**, subjected to heat treatment and drawing treatment, and wound around a winder **12**. The surface of 2FR is preferably a mirror surface, and the surfaces of 1DR, 2DR, 3DR, and RR are preferably a satin surface.

[0061] The first-stage drawing is performed between 2FR and 1DR, and the temperature of 2FR (surface temperature of the roller) is 60-90° C. and the temperature of 1DR is 100-225° C. The second-stage drawing is performed between 1DR and 2DR, and the temperature of 2DR (surface temperature of the roller) is 150-230° C. The third-stage drawing is performed between 2DR and 3DR, and the temperature of 3DR (the surface temperature of the roller) is 180-240° C.

[0062] Herein, in the production of the polyamide-46 multifilament of the present invention, it is important that the draw ratio in the third-stage drawing step, that is, the final drawing step is 1.00-1.10 times, and the draw ratio is more preferably 1.00-1.05 times.

[0063] As described in Patent Document 1 or 2, the polyamide-46 polymer is known to have a significantly higher crystallization rate than conventional aliphatic polyamides such as polyamide 66 and polyamide 6. That is, it is easily expected that the crystallization of the fiber is sufficiently advanced after the first-stage drawing with a high draw ratio or after the second-stage drawing. There is no room for drawing the fiber again in such a final drawing step.

[0064] Setting the drawing in the final drawing step within the above range can provide a multifilament in which the amorphous orientation is suppressed from becoming excessive and which exhibits the high-temperature dimensional stability. If the draw ratio is larger than the above range, the amorphous orientation increases, and thus the multifilament is easily thermally shrunk. Such a multifilament deteriorates the high-temperature dimensional stability, and cannot achieve M' (R.T.)−M(R. T.) defined in the present invention. If the draw ratio is lower than 1.00 times, the tension is lowered, and thus yarn swinging is large and yarn making becomes difficult.

[0065] Thus, the polyamide-46 multifilament of the present invention can be obtained.

[0066] If the sewing thread for airbags using the polyamide-46 multifilament of the present invention is produced, the sewing thread for airbags can be produced by a known processing method.

EXAMPLES

[0067] Hereinafter, the present invention will be described in more detail with reference to Examples. However, the present invention is not to be construed as being limited to the aspects specifically shown in Examples. The definition and measurement method of each characteristic in the present invention are as follows.

Sulfuric Acid Relative Viscosity

[0068] 1 g of a sample was dissolved in 100 ml of 98% sulfuric acid, and measurement was performed at 25° C. using an Ostwald viscometer. An average value of two measurements was used.

Total Fineness and Single Filament Fineness of Multifilament

[0069] Measurement was performed according to JIS L1090 (1999).

Strength and Elongation for Multifilament

[0070] Tensile strength and a degree of elongation measured by the method of JIS L1013 (1999) were defined as strength and elongation. Measurement was performed under conditions of a gauge length of 250 mm and a tensile speed of 300 mm/min using a Tensilon universal tester RTG-1250 with a high and low temperature tank manufactured by A & D Co., Ltd. The measurement was performed 5 times for each sample, and an average value thereof was obtained.

Degree of Elongation After Stretching 10 Times

[0071] There was repeated a specified number of times an operation of holding a multifilament having a gauge length of 250 mm with a chuck of a Tensilon universal tester RTG-1250 with a high and low temperature tank manufactured by A & D Co., Ltd, pulling the multifilament at a speed of 300 mm/min until a load of 2.0 cN/dtex was reached, and then returning the multifilament to the original chuck interval at a speed of 300 mm/min.

[0072] In the repeated tensile test, the elongation when a load of 0.1 cN/dtex was shown in the return operation of the 10th cycle was defined as a degree of elongation E10 after stretching 10 times.

[0073] Herein, the measured value at ordinary temperature is represented as E10 (R.T.), the measured value under an environment of 100° C. as E10 (100° C.), and the measured value at ordinary temperature after the heat treatment as E10' (R.T.), and the heat treatment was performed in an environment at 120° C. for 24 hours.

[0074] The measured value is an index indicating the stretchability of the multifilament, and as the E10 (100° C.) is smaller, the return after tension at a high temperature is better, indicating that the stretchability is excellent at a high temperature.

[0075] A value obtained by subtracting E10 (R.T.) from E10' (R.T.) is an index indicating a change in stretchability after aging at a high temperature.

Elongation Under Load of 2.0 cN/dtex

[0076] In the SS curve at the time of measuring the strength and elongation, the elongation when a load of 2.0 cN/dtex was applied was extracted. The average value of values extracted from five measurement samples for strength and elongation was defined as M.

[0077] Herein, the measured value at ordinary temperature is represented as M (R.T.), the measured value under an environment of 100° C. as M (100° C.), and the measured value at ordinary temperature after the heat treatment as M' (R.T.), and the heat treatment was performed in an environment at 120° C. for 24 hours.

[0078] A value obtained by subtracting M (R.T.) from M (100° C.) is an index indicating the high-temperature dimensional stability.

[0079] A value obtained by subtracting M (R. T.) from M' (R.T.) is an index indicating a change in dimensional stability after aging at a high temperature.

Yarn Productivity

[0080] In the step of melt-spinning a polyamide 46 polymer, drawing the spun undrawn yarn in multiple stages, and drawing in at least the first drawing step and the final drawing step, yarn breakage and fuzz amount when production was performed as in the following Examples and Comparative Examples were evaluated as follows.

[0081] S: The yarn breakage in 1 hour is less than 0.1 times, and the number of fuzzes at 10,000 m is less than 1.

[0082] A: The yarn breakage in 1 hour is 0.1 times or more, and the number of fuzzes at 10, 000 m is 1 or more.

[0083] B: Yarn breakage frequently occurs, and raw yarn collection is impossible.

Example 1

Method for Producing Polyamide-46 Multifilament

[0084] The production step shown in FIG. **1** was used.

[0085] A 5 wt % aqueous solution of copper acetate as a heat stabilizer was added to and mixed with a polyamide 46 chip (Stanyl (registered trademark), melting point 292° C.) having a sulfuric acid relative viscosity of 3.9, and 70 ppm as copper relative to the polymer weight was added and adsorbed.

[0086] Then, a 50 wt % aqueous solution of potassium iodide and a 20 wt % aqueous solution of potassium bromide were each added and adsorbed so as to be 1000 ppm as potassium relative to the polymer weight, and the chip moisture content was adjusted to 700 ppm by a known drying facility.

[0087] The polyamide 46 chips were melted at 305° C. under vacuum in an extruder spinning machine.

[0088] The molten polymer was weighed so as to have a total fineness of 940 dtex by a gear pump, filtered through a 20 u metal nonwoven fabric filter in a spinning pack, and spun from the spinneret **1** having 136 round holes. The heating hood **2** having a heating hood length of 15 cm was placed 3 cm below the spinneret surface, and heated so that the in-cylinder atmospheric temperature was 300° C. and the spun yarn passed through the atmosphere at 300° C. The in-cylinder atmosphere temperature is an air temperature at a portion 1 cm away from the inner wall at the center of the heating hood length.

[0089] The cross flow cooling device **3** for blowing air from one direction was attached immediately below the heating hood, and cold air at 20° C. was blown at a speed of 35 m/min to the yarn that had passed through the heating hood to cool and solidify the yarn, and then an oil solution was applied to the yarn with the oil supply device **4**.

[0090] An undrawn yarn to which the oil solution had been applied was wound and taken up in 1FR6 rotating at a surface speed of 600 m/min, and then drawn at a total draw ratio of 4.70. The take-up yarn was continuously stretched by 5% between the take-up roller **6** and 2FR7 without being wound up once, and then successively drawn in the first stage at a rotation speed ratio of 3.27 times, then drawn in the second stage at a rotation speed ratio of 1.30 times, and finally drawn in the third stage at a rotation speed ratio of 1.05 times, and then wound up at a speed of 2600 m/min.

[0091] The roller surfaces of 1FR and 2FR were mirror finished, and 1DR, 2DR, 3DR, and RR were satin finished. The roller temperatures of 1FR were non-heated, 2FR was 80° C., 1DR was 175° C., 2DR was 180° C., 3DR was 230° C., and RR was 150° C.

[0092] Such melt spinning and drawing provided the polyamide-46 multifilament. The obtained fiber properties were evaluated and shown in Table 1.

Example 2

[0093] The procedure was performed in the same manner as in Example 1, except that the third stage draw ratio (final draw ratio) was changed as shown in Table 1 at the time of spinning the polyamide-46 multifilament.

Example 3

[0094] The procedure was performed in the same manner as in Example 1, except that the total fineness of the polyamide-46 multifilament was changed as shown in Table 1.

Example 4

[0095] The procedure was performed in the same manner as in Example 1, except that the total fineness and total draw ratio of the polyamide-46 multifilament were changed as shown in Table 1.

Example 5

[0096] The procedure was performed in the same manner as in Example 1, except that the total fineness, total draw ratio, and final draw ratio of the polyamide-46 multifilament were changed as shown in Table 1.

Examples 6 and 7

[0097] The procedure was performed in the same manner as in Example 1, except that the total draw ratio and final draw ratio of the polyamide-46 multifilament were changed as shown in Table 1.

Example 8

[0098] The procedure was performed in the same manner as in Example 1, except that a heat stabilizer (copper acetate, potassium iodide, and potassium bromide) was not added at the time of preparing the polyamide 46 chips.

Comparative Examples 1 and 2

[0099] The procedure was performed in the same manner as in Example 1, except that the final draw ratio was changed as shown in Table 1.

Comparative Example 3

[0100] The procedure was performed in the same manner as in Example 1, except that melt spinning in an extruder spinning machine was performed under normal pressure.

Comparative Example 4

[0101] The procedure was performed in the same manner as in Example 1, except that the total fineness and total draw ratio of the polyamide-46 multifilament were changed as shown in Table 1.

Comparative Examples 5 and 6

[0102] The procedure was performed in the same manner as in Example 2, except that the total draw ratio of the polyamide-46 multifilament was changed as shown in Table 1.

Comparative Example 7

[0103] The procedures was performed in the same manner as in Example 1, except that a polyamide 66 polymer having a sulfuric acid relative viscosity of 3.8 was melt-spun at 280° C. under vacuum using an extruder spinning machine.

Comparative Example 8

[0104] The procedure was performed in the same manner as in Example 1, except that a polyamide 6 polymer having a sulfuric acid relative viscosity of 3.8 was melt-spun at 260° C. under vacuum using an extruder spinning machine.

TABLE 1-1

	Unit	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Comparative Example 1
Material polymer	—	PA46	PA46	PA46	PA46	PA46	PA46	PA46	PA46	PA46
Whether heat stabilizer contains or not	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Environment in the melt spinning process	—	Under vacuum	Under vacuum	Under vacuum	Under vacuum	Under vacuum	Under vacuum	Under vacuum	Under vacuum	Under vacuum
Total draw ratio	Times	4.70	4.70	4.70	4.20	4.20	4.10	5.10	4.70	4.70
Final draw ratio	Times	1.05	1.00	1.05	1.05	1.08	1.00	1.00	1.05	1.20
Total fineness	dtex	940	940	1400	470	470	940	940	940	940
Breaking strength	cN/dtex	7.4	7.6	7.4	7.4	7.3	6.6	8.2	7.4	6.9
Elongation at break	%	20.8	21.4	19.7	20.6	20.2	25.2	18.3	21.0	20.2
Sulfuric acid relative viscosity ηr	—	3.6	3.6	3.7	3.6	3.6	3.7	3.5	3.6	3.6
Residual elongation rate after stretching 10 times at 100° C. E10 (100° C.)	%	0.60	0.60	0.70	0.60	0.80	0.80	0.30	0.60	0.90
Difference of elongation at 2.0 cN/dtex between 100° C. and room temperature	%	0.00	−0.10	0.10	0.00	0.20	−0.25	0.30	0.00	0.70
Difference of residual elongation after stretching 10 times between before and after heat treatment	%	−0.80	−0.60	−0.40	−0.40	−0.40	−0.60	−0.40	0.30	−0.40

TABLE 1-1-continued

	Unit	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Comparative Example 1
Difference of elongation at 2.0 cN/dtex between before and after heat treatment	%	−1.50	−1.30	−1.10	−1.10	−0.40	−1.50	−1.30	1.20	0.30
Yarn productivity	—	S	S	S	S	S	S	S	S	A

PA 46: polyamide 46,
PA 66: polyamide 66,
PA 6: polyamide 6

TABLE 1-2

	Unit	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8
Material polymer	—	PA46	PA46	PA46	PA46	PA46	PA66	PA6
Whether heat stabilizer contains or not	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Environment in the melt spinning process	—	Under vacuum	Under normal pressure	Under vacuum	Under vacuum	Under vacuum	Under vacuum	Under vacuum
Total draw ratio	Times	4.70	4.70	4.20	3.60	5.40	5.10	5.10
Final draw ratio	Times	0.90	1.05	1.05	1.00	1.00	1.05	1.05
Total fineness	dtex	—	940	235	940	—	940	940
Breaking strength	cN/dtex	—	5.7	5.8	5.7	—	8.6	8.1
Elongation at break	%	—	22.2	20.4	28.9	—	22.1	22.0
Sulfuric acid relative viscosity ηr	—	—	3.1	3.3	3.7	—	3.7	3.7
Residual elongation rate after stretching 10 times at 100° C. E10 (100° C.)	%	—	1.25	1.20	1.15	—	1.20	1.30
Difference of elongation at 2.0 cN/dtex between 100° C. and room temperature	%	—	0.20	0.20	−0.35	—	0.70	0.90
Difference of residual elongation after stretching 10 times between before and after heat treatment	%	—	−1.50	−1.40	−1.50	—	0.40	0.10
Difference of elongation at 2.0 cN/dtex between before and after heat treatment	%	—	−1.10	−1.00	−1.10	—	2.10	2.50
Yarn productivity	—	B	A	A	S	B	S	S

PA 46: polyamide 46,
PA 66: polyamide 66,
PA 6: polyamide 6

[0105] The production conditions in Examples 1 to 6 and Comparative Examples 1 to 8 and the results of evaluating the physical properties of the obtained polyamide-46 multifilament are shown in Table 1.

[0106] As is clear from Table 1, the polyamide-46 multifilament of the present invention has high strength, high thermal dimensional stability, and excellent stretchability.

[0107] On the other hand, the conventional aliphatic polyamide multifilament shown in Comparative Examples 7 and 8 has high strength, but has low stretchability and insufficient high-temperature dimensional stability. When applied as the sewing thread for airbags, it is impossible to suppress misalignment and improve internal pressure retention performance.

[0108] In Comparative Example 3, hydrolysis is promoted by melting under normal pressure, resulting in the multifilament having low crystal orientation. Therefore, a multifilament fails to have high strength, and the stretchability is disadvantageous.

[0109] In Comparative Example 4, the polymer retention time in the spinning machine becomes longer with the decrease in the polymer discharge amount, and thus, thermal deterioration tends to occur during melting. The strength of the polyamide-46 multifilament was reduced, and E10 (100° C.) exceeded 1.0.

[0110] Furthermore, as in Comparative Example 1, when the final draw ratio in the final drawing step is more than 1.10 in the production of the polyamide-46 multifilament having high strength, the amorphous orientation increases, thus resulting in the multifilament easily undergoing thermal shrinkage. Therefore, it was confirmed that the high-temperature dimensional stability M (100° C.)−M (R.T.) was more than 0.5. On the other hand, in Comparative Example 2, the final draw ratio in the final drawing step was less than 1.0, and thus yarn breakage frequently occurred, and raw yarn collection was difficult.

[0111] Examples 2 and 6 and Comparative Example 5 were examples in which the crystal structure of the polyamide-46 multifilament was controlled, but the crystal orientation was smaller as the draw ratio was shifted to low draw ratio, and the influence on the stretchability was confirmed. Similarly, in Examples 2 and 7 and Comparative Example 6, the amorphous orientation was increased as the draw ratio was shifted to high draw ratio, and the influence on the high-temperature dimensional stability was confirmed. In Comparative Example 6, the high draw ratio resulted in deterioration of the yarn productivity.

INDUSTRIAL APPLICABILITY

[0112] The polyamide-46 multifilament of the present invention has high strength and high heat resistance, and is suitable for sewing thread for the sewing thread for airbags. Furthermore, excellent high-temperature dimensional stability and stretchability induce a sewing portion filling effect in use of the sewing thread for airbags. It is possible to provide an airbag that achieves reduction of air leakage from a sewing portion due to a high-temperature and high-output inflator and improvement in internal pressure retention performance, which have been problems heretofore.

DESCRIPTION OF REFERENCE SIGNS

[0113] **1**: Spinneret
[0114] **2**: Heating hood
[0115] **3**: Cross flow cooling device
[0116] **4**: Oil supply device
[0117] **5**: Yarn
[0118] **6**: Take-up roller (1FR)
[0119] **7**: Feeding roller (2FR)
[0120] **8**: First drawing roller (1DR)
[0121] **9**: Second drawing roller (2DR)
[0122] **10**: Third drawing roller (3DR)
[0123] **11**: Relaxing roller (RR)
[0124] **12**: Winder

1. A polyamide-46 multifilament comprising the following physical properties (1) to (3):

(1) a strength of 6.0-9.0 cN/dtex and an elongation of 15-30%;

(2) E10(100° C.)<1.0% wherein E10(100° C.) is a degree of elongation after stretching 10 times in an environment of 100° C.; and

(3) M (100° C.)−M (R.T.)<0.5% wherein M (R.T.) is an elongation under a load of 2.0 cN/dtex and ordinary temperature, and M (100° C.) is an elongation under a load of 2.0 cN/dtex and an environment of 100° C.

2. The polyamide-46 multifilament according to claim **1**, comprising the following physical properties (4) and (5);

(4) E10' (R.T.)−E10(R.T.)≤0% wherein E10(R.T.) is a degree of elongation after stretching 10 times under ordinary temperature, and E10' (R.T.) is a degree of elongation after stretching 10 times under ordinary temperature after heat treatment at 120° C. for 24 hours; and

(5) M' (R.T.)−M (R.T.)≤0% wherein M (R.T.) is an elongation under a load of 2.0 cN/dtex and ordinary temperature, and M' (R.T.) is an elongation under a load of 2.0 cN/dtex and ordinary temperature after heat treatment at 120° C. for 24 hours.

3. The polyamide-46 multifilament according to claim **1**, having a total fineness of 300-2300 dtex and a single filament fineness of 2-20 dtex.

4. The polyamide-46 multifilament according to claim **1**, wherein sulfuric acid relative viscosity ηr is $3.0<\eta r<4.5$.

5. A sewing thread for airbags, comprising the polyamide-46 multifilament according to claim **1**.

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